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Nagai

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[54] **SYSTEM AND METHOD FOR CONTROLLING THE IGNITION TIMING OF AN INTERNAL COMBUSTION ENGINE**

[75] Inventor: **Masaaki Nagai**, Fuchu, Japan

[73] Assignee: **Fuji Jukogyo Kabushiki Kaisha**, Tokyo, Japan

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[30] **Foreign Application Priority Data**

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[51] **Int. Cl.**[4] **F02D 41/22**; F02P 5/14

[52] **U.S. Cl.** **123/425**; 123/435

[58] **Field of Search** 123/419, 425, 435, 436

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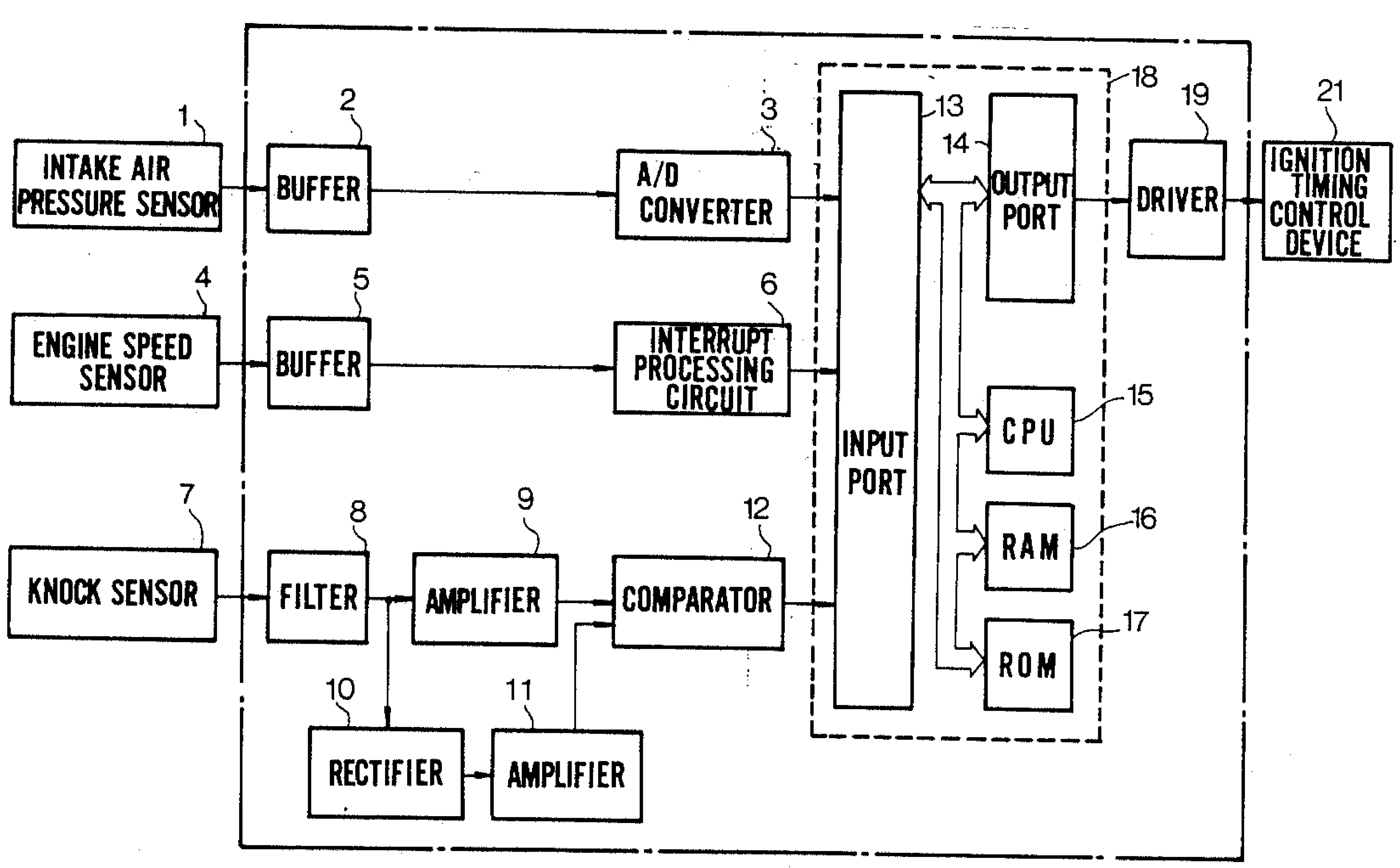
Primary Examiner—Willis R. Wolfe, Jr.
Attorney, Agent, or Firm—Martin A. Farber

[57] **ABSTRACT**

A system and method for deciding the ignition timing at the acceleration of an engine and the steady state. The system has an acceleration ignition timing correction subroutine and a steady state ignition timing correction subroutine. In the acceleration ignition timing subroutine, a basic ignition timing obtained in the steady state ignition timing correction subroutine is corrected by a quantity read from a table so as to sufficiently advance the ignition timing for the acceleration and the steady state.

2 Claims, 10 Drawing Sheets



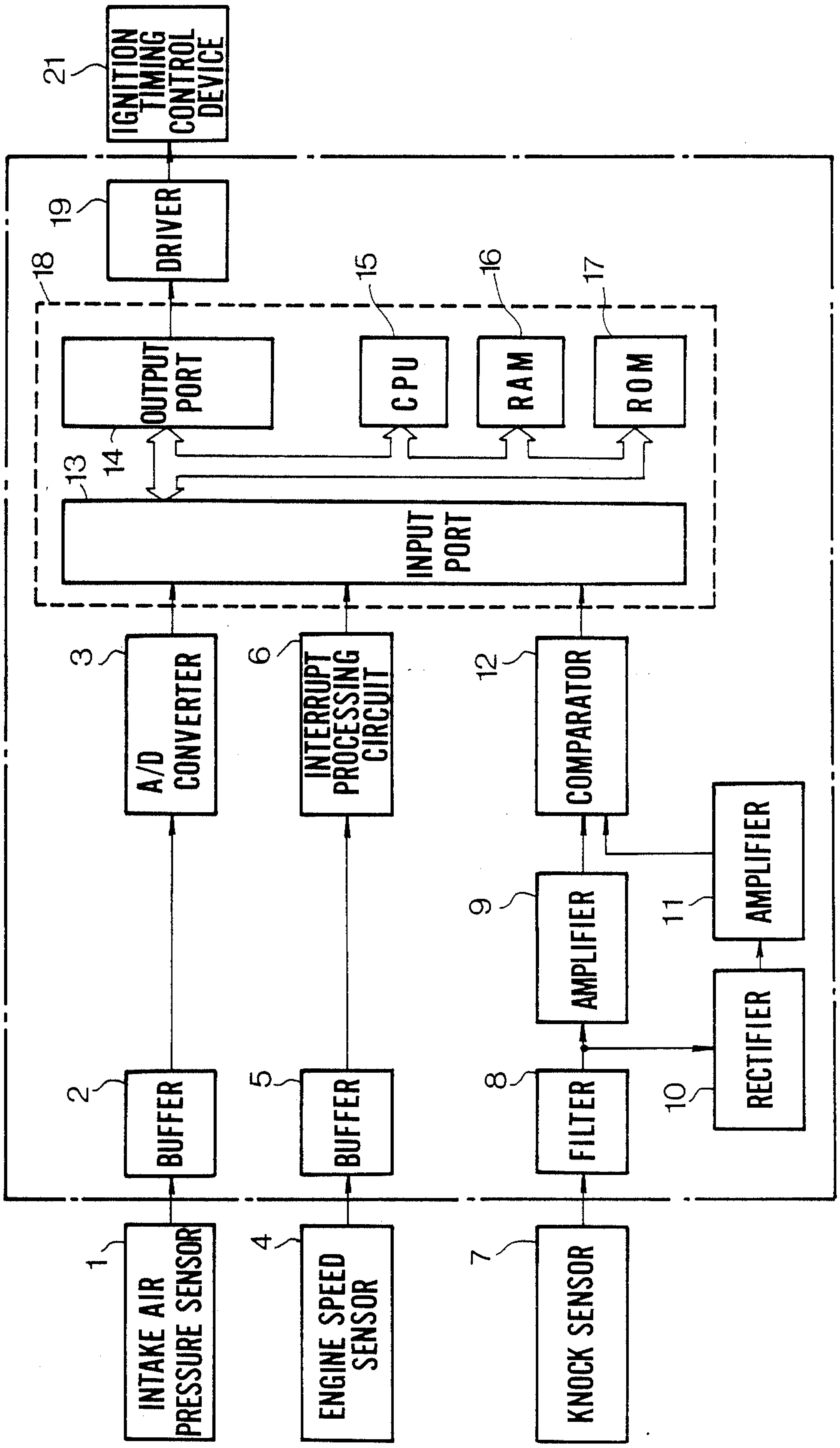

IGNITION TIMING CONTROL DEVICE
21
DRIVER
19
18
OUTPUT PORT
14
13
CPU
15
RAM
16
ROM
17
INPUT PORT
A/D CONVERTER
3
INTERRUPT PROCESSING CIRCUIT
6
COMPARATOR
12
BUFFER
2
BUFFER
5
FILTER
8
AMPLIFIER
9
RECTIFIER
10
AMPLIFIER
11
INTAKE AIR PRESSURE SENSOR
1
ENGINE SPEED SENSOR
4
KNOCK SENSOR
7

FIG. 1

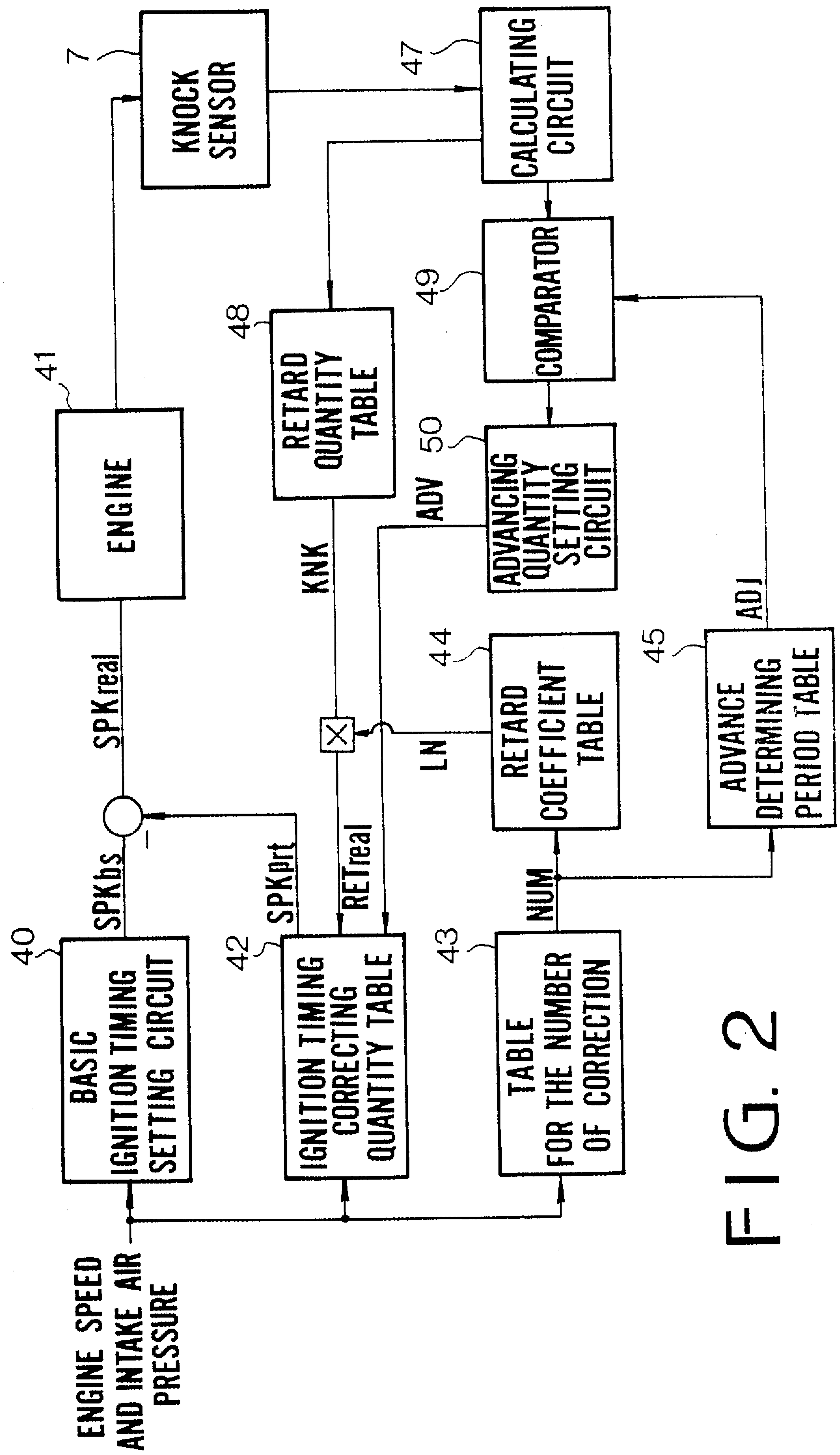

KNOCK SENSOR
7
CALCULATING CIRCUIT
47
COMPARATOR
49
ENGINE
41
RETARD QUANTITY TABLE
48
ADVANCING QUANTITY SETTING CIRCUIT
50
ADV
KNK
SPKreal
RETARD COEFFICIENT TABLE
44
LN
ADVANCE DETERMINING PERIOD TABLE
45
ADJ
SPKbs
SPKprt
RETreal
NUM
BASIC IGNITION TIMING SETTING CIRCUIT
40
IGNITION TIMING CORRECTING QUANTITY TABLE
42
TABLE FOR THE NUMBER OF CORRECTION
43
ENGINE SPEED AND INTAKE AIR PRESSURE

FIG. 2

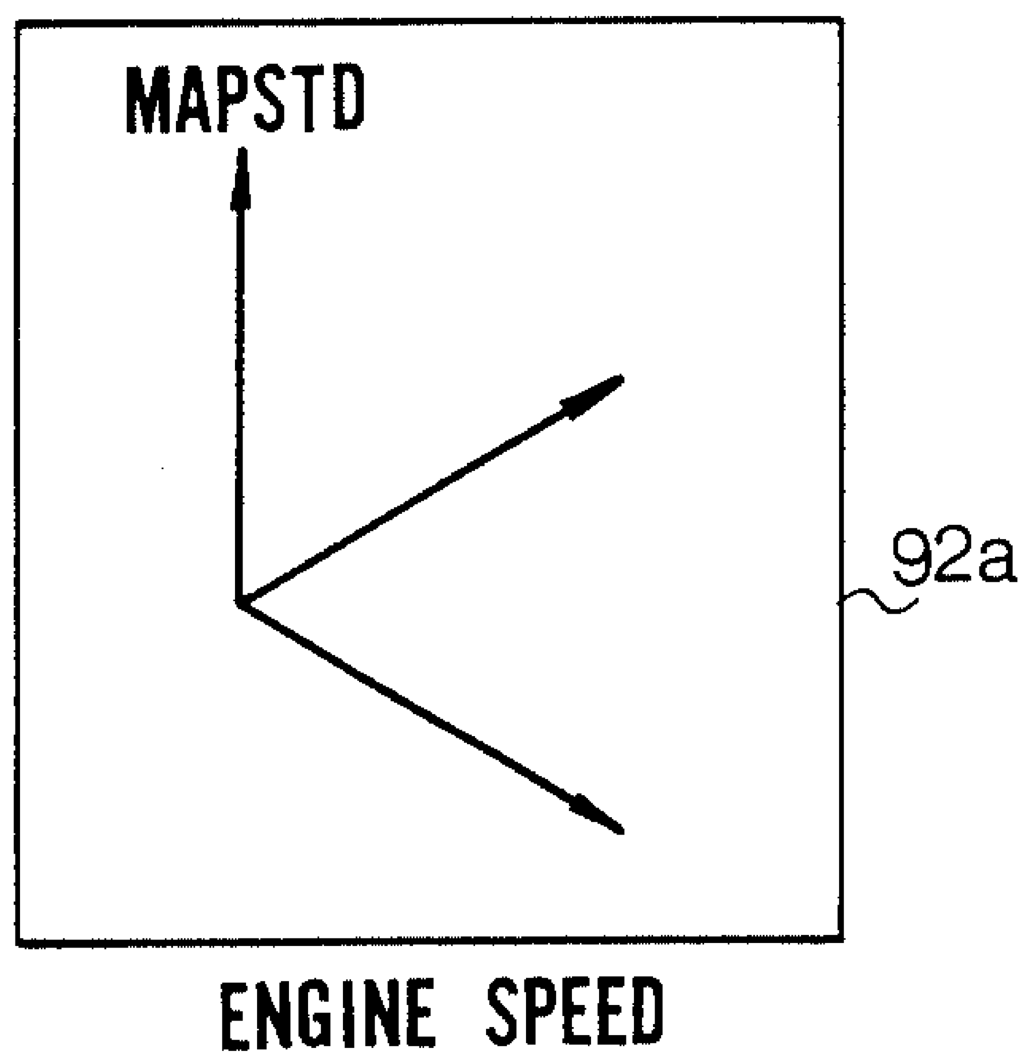


FIG. 3a

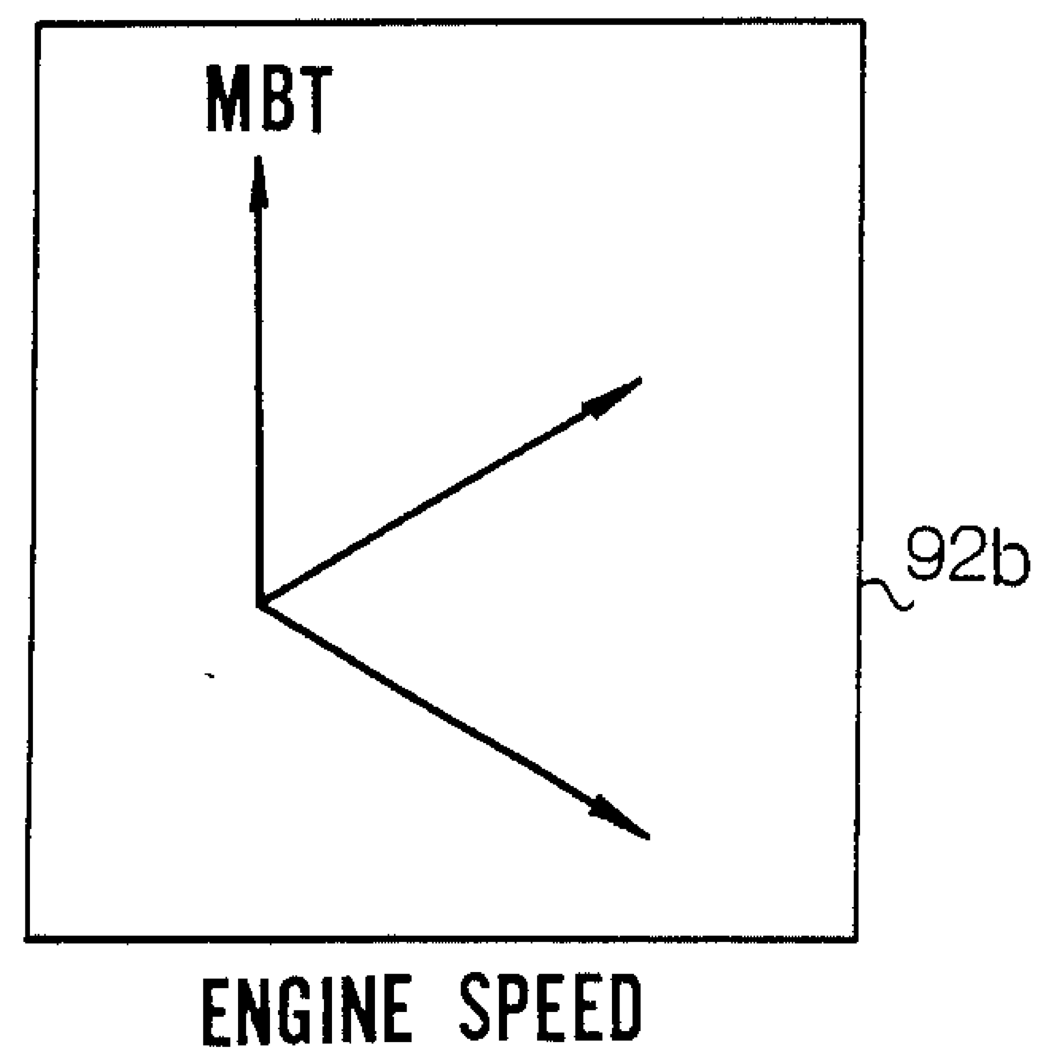


FIG. 3b

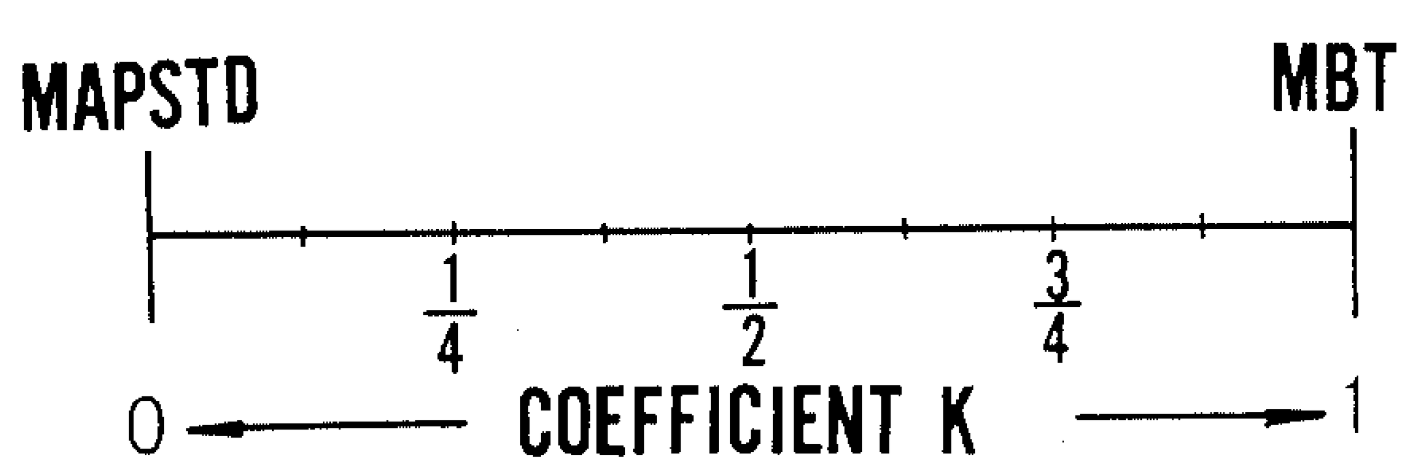


FIG. 4

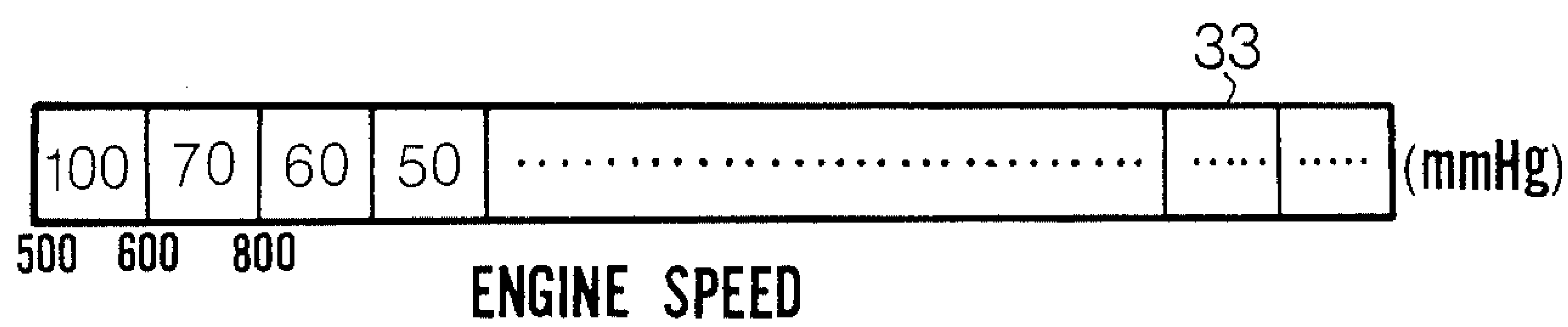


FIG. 5a

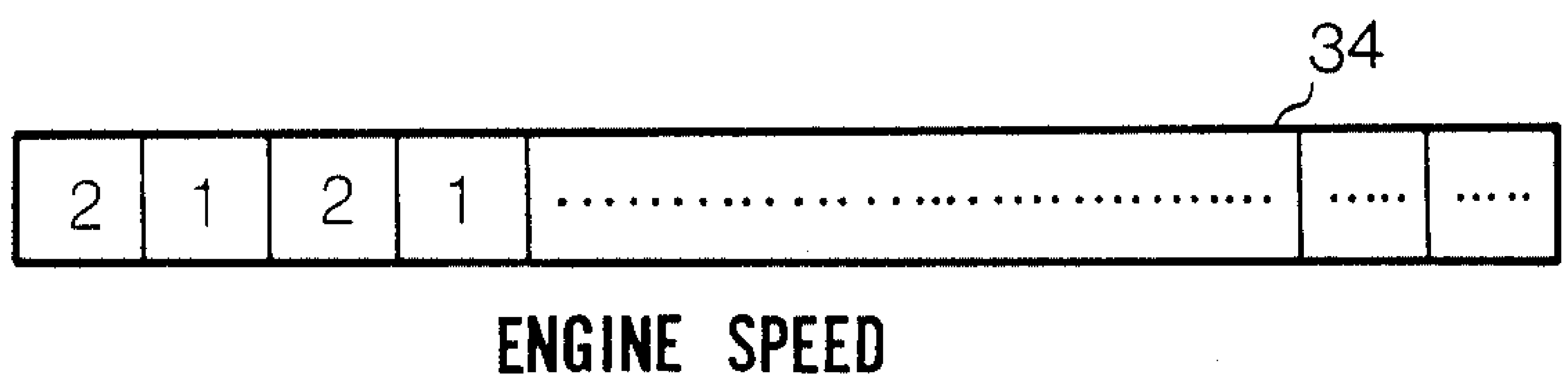


FIG. 5b

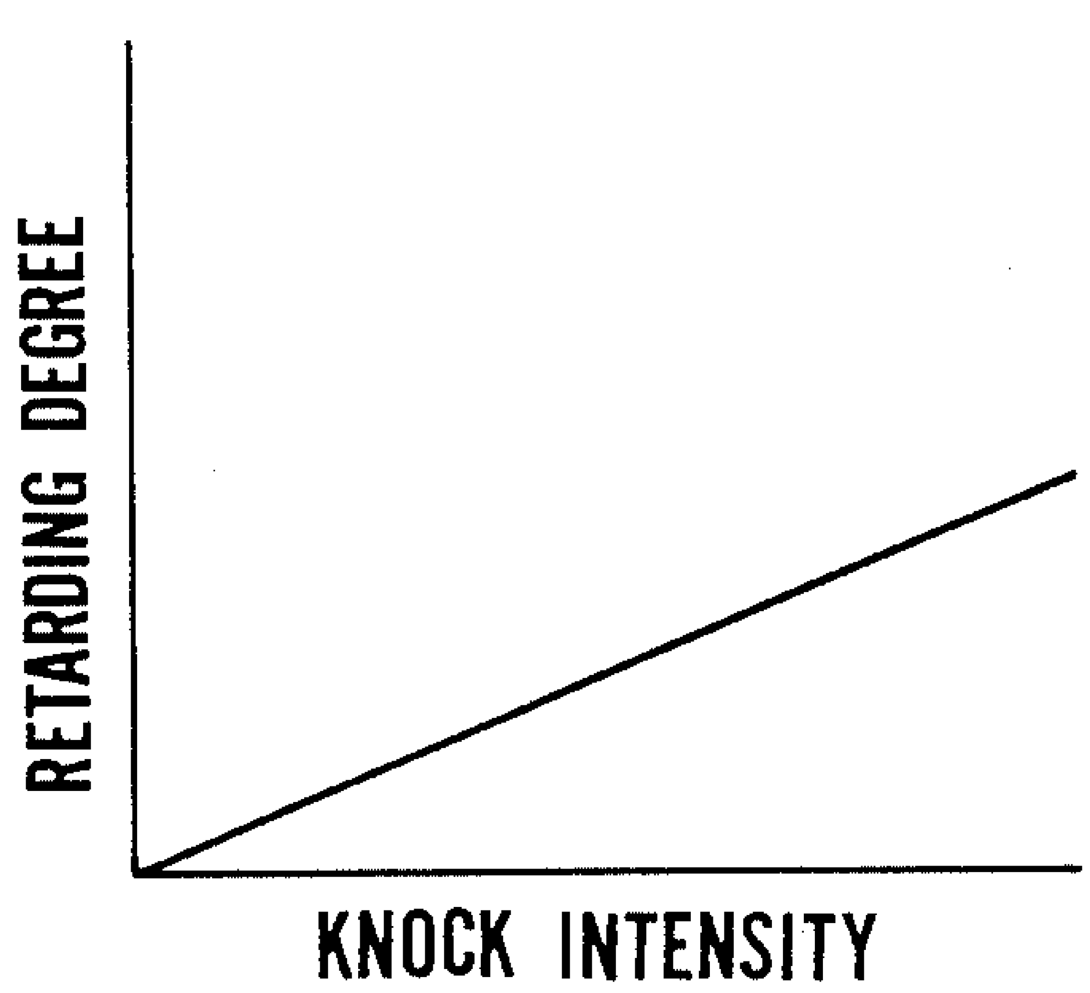


FIG. 5c

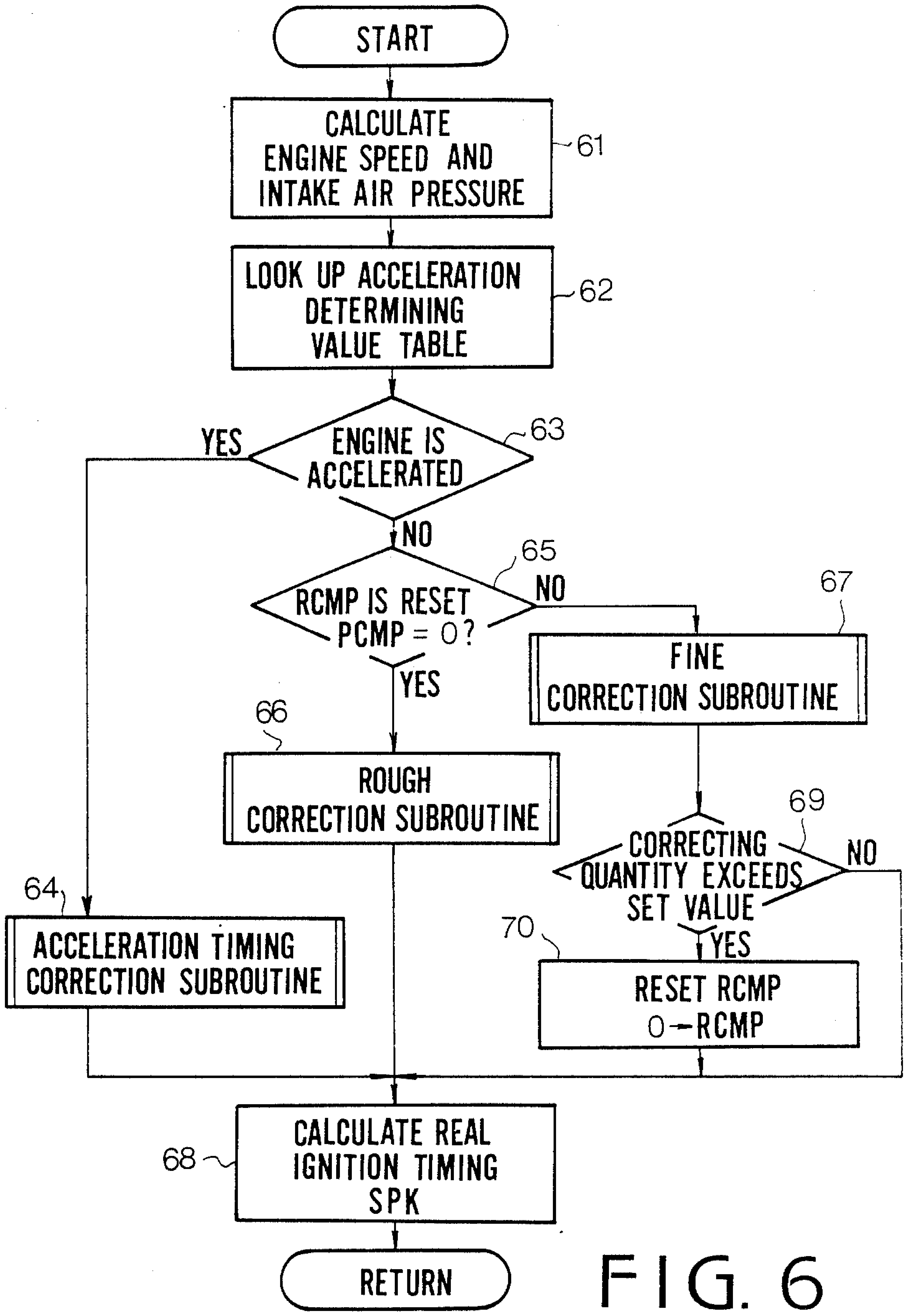

START
CALCULATE ENGINE SPEED AND INTAKE AIR PRESSURE
61
LOOK UP ACCELERATION DETERMINING VALUE TABLE
62
ENGINE IS ACCELERATED
63
YES
NO
RCMP IS RESET PCMP = 0?
65
NO
YES
FINE CORRECTION SUBROUTINE
67
ROUGH CORRECTION SUBROUTINE
66
CORRECTING QUANTITY EXCEEDS SET VALUE
69
NO
YES
70
RESET RCMP 0→RCMP
64
ACCELERATION TIMING CORRECTION SUBROUTINE
CALCULATE REAL IGNITION TIMING SPK
68
RETURN

FIG. 6

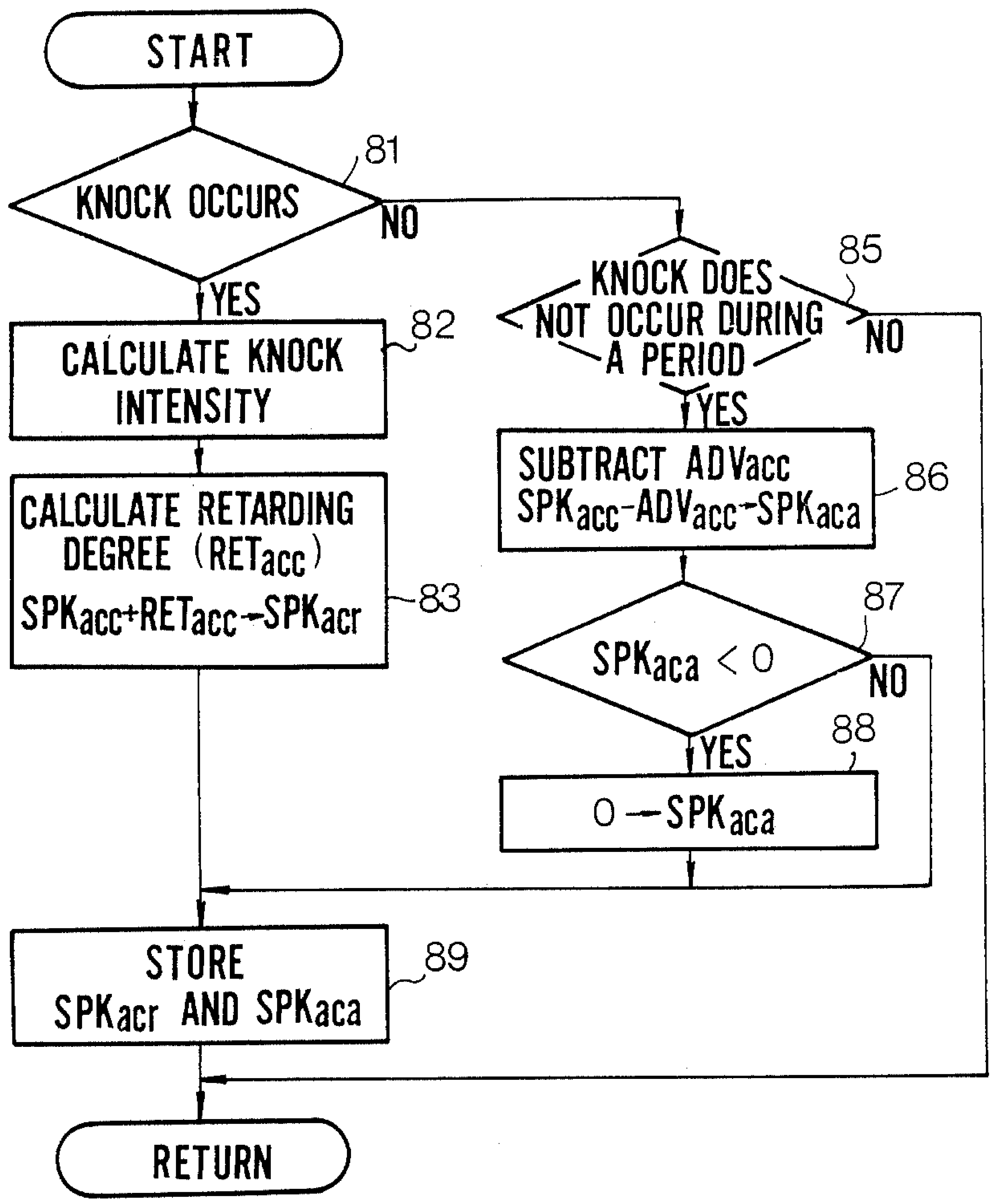

START
KNOCK OCCURS
81
NO
YES
CALCULATE KNOCK INTENSITY
82
CALCULATE RETARDING DEGREE (RETacc)
SPKacc+RETacc→SPKacr
83
KNOCK DOES NOT OCCUR DURING A PERIOD
85
NO
YES
SUBTRACT ADVacc
SPKacc-ADVacc→SPKaca
86
SPKaca < 0
87
NO
YES
88
0→SPKaca
STORE
SPKacr AND SPKaca
89
RETURN

FIG. 7

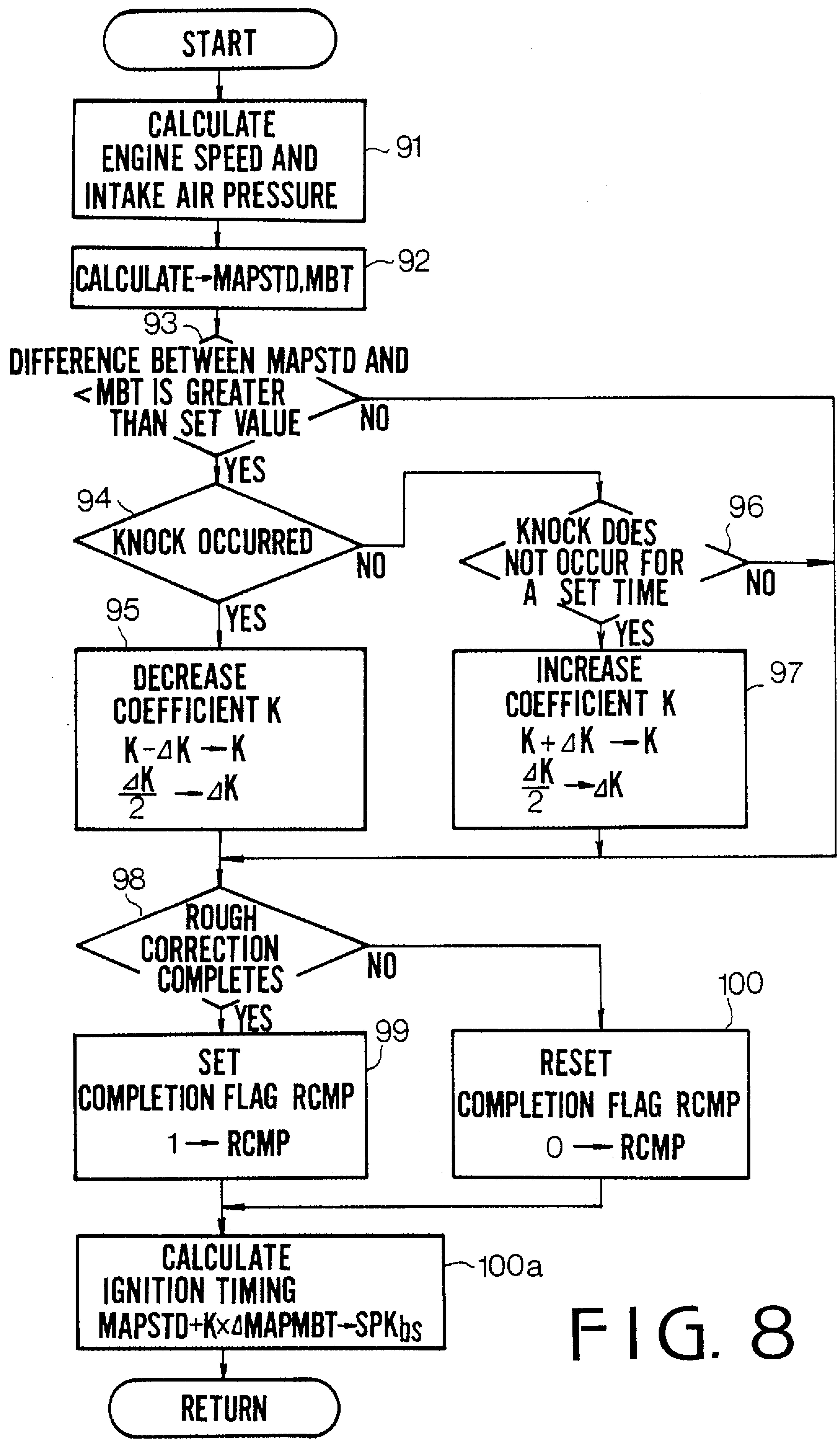

START
CALCULATE ENGINE SPEED AND INTAKE AIR PRESSURE
91
CALCULATE→MAPSTD,MBT
92
93
DIFFERENCE BETWEEN MAPSTD AND MBT IS GREATER THAN SET VALUE
NO
YES
94
KNOCK OCCURRED
NO
YES
KNOCK DOES NOT OCCUR FOR A SET TIME
96
NO
YES
95
DECREASE COEFFICIENT K
K−ΔK → K
ΔK/2 → ΔK
INCREASE COEFFICIENT K
K+ΔK → K
ΔK/2 → ΔK
97
98
ROUGH CORRECTION COMPLETES
NO
YES
100
SET COMPLETION FLAG RCMP
1 → RCMP
99
RESET COMPLETION FLAG RCMP
0 → RCMP
CALCULATE IGNITION TIMING
MAPSTD+K×ΔMAPMBT→SPKbs
100a
RETURN

FIG. 8

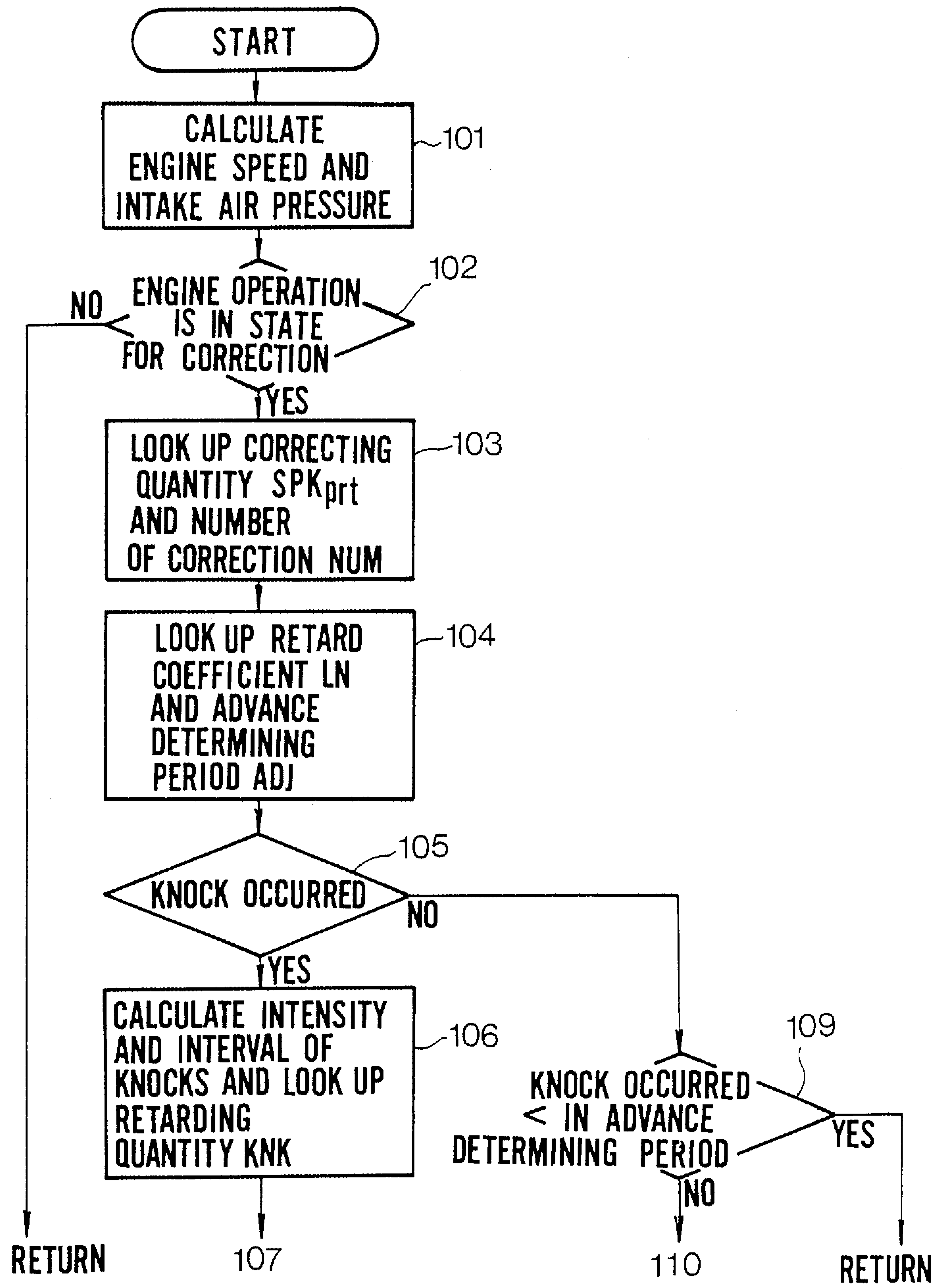

START
CALCULATE ENGINE SPEED AND INTAKE AIR PRESSURE
101
ENGINE OPERATION IS IN STATE FOR CORRECTION
102
NO
YES
LOOK UP CORRECTING QUANTITY SPKprt AND NUMBER OF CORRECTION NUM
103
LOOK UP RETARD COEFFICIENT LN AND ADVANCE DETERMINING PERIOD ADJ
104
KNOCK OCCURRED
105
NO
YES
CALCULATE INTENSITY AND INTERVAL OF KNOCKS AND LOOK UP RETARDING QUANTITY KNK
106
KNOCK OCCURRED < IN ADVANCE DETERMINING PERIOD
109
YES
NO
RETURN
107
110
RETURN

FIG. 9a

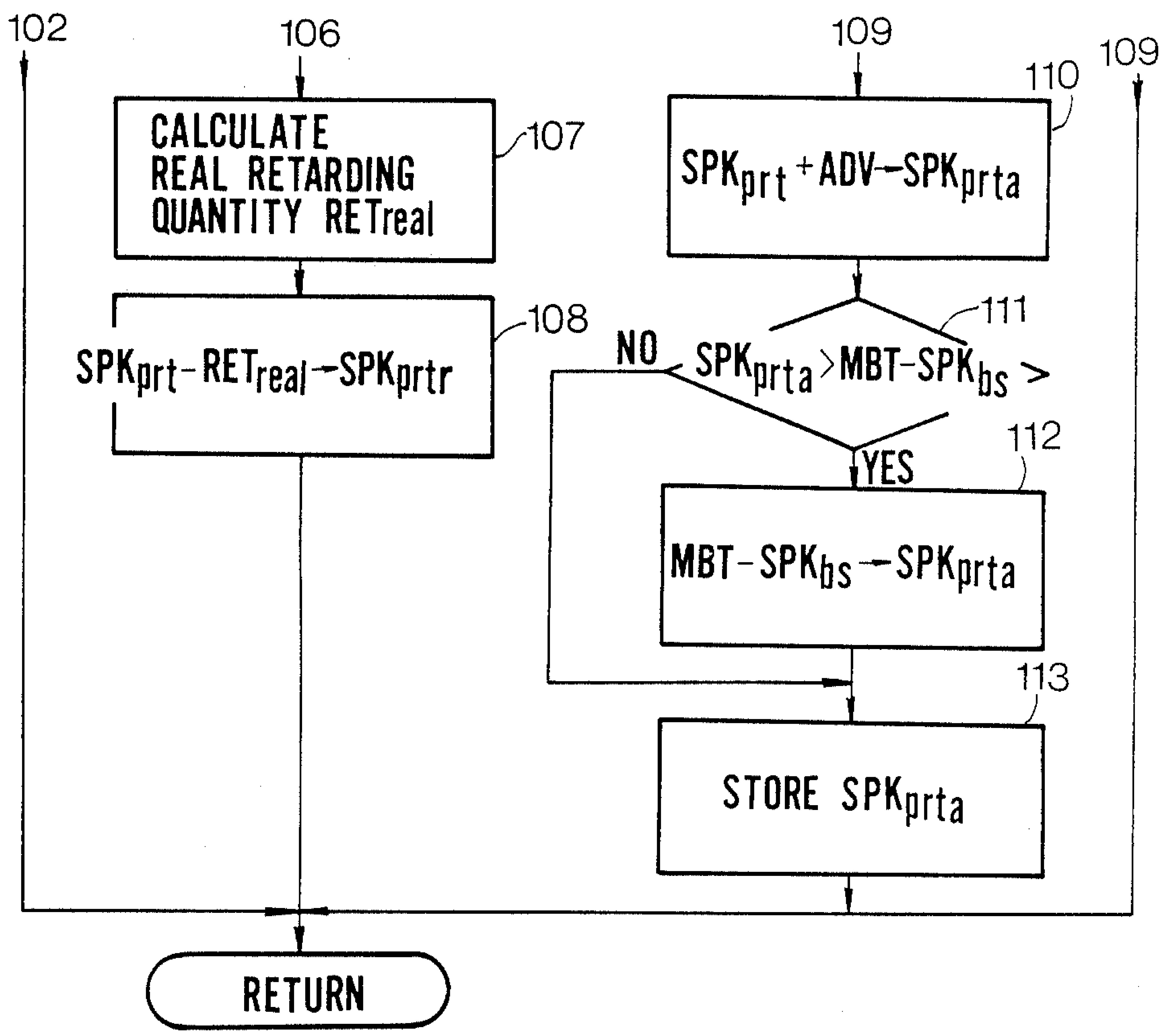

102
106
CALCULATE REAL RETARDING QUANTITY RETreal
107
SPKprt-RETreal→SPKprtr
108
109
SPKprt+ADV→SPKprta
110
109
SPKprta>MBT-SPKbs >
111
NO
YES
MBT-SPKbs→SPKprta
112
STORE SPKprta
113
RETURN

FIG. 9b

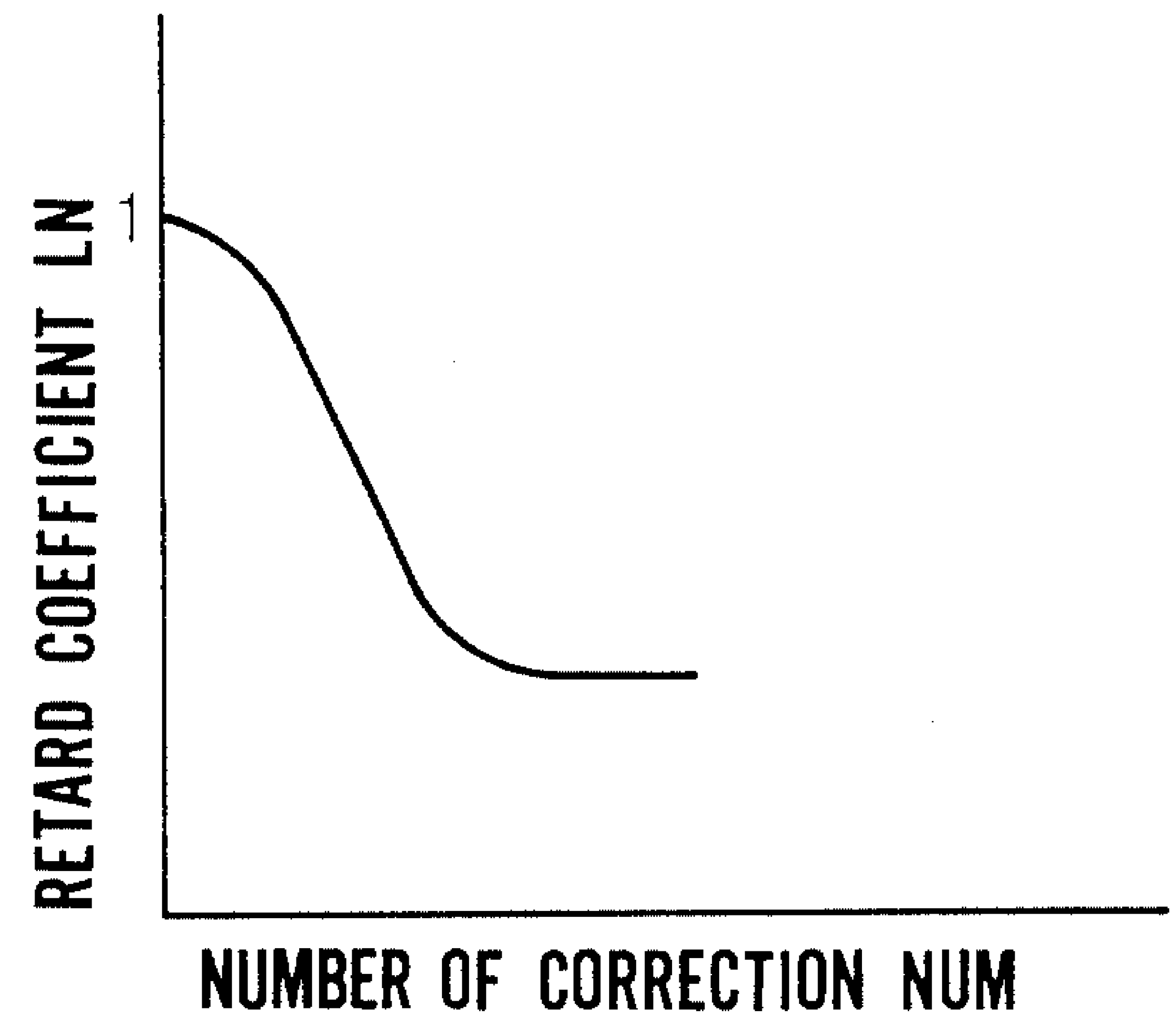


FIG. 10a

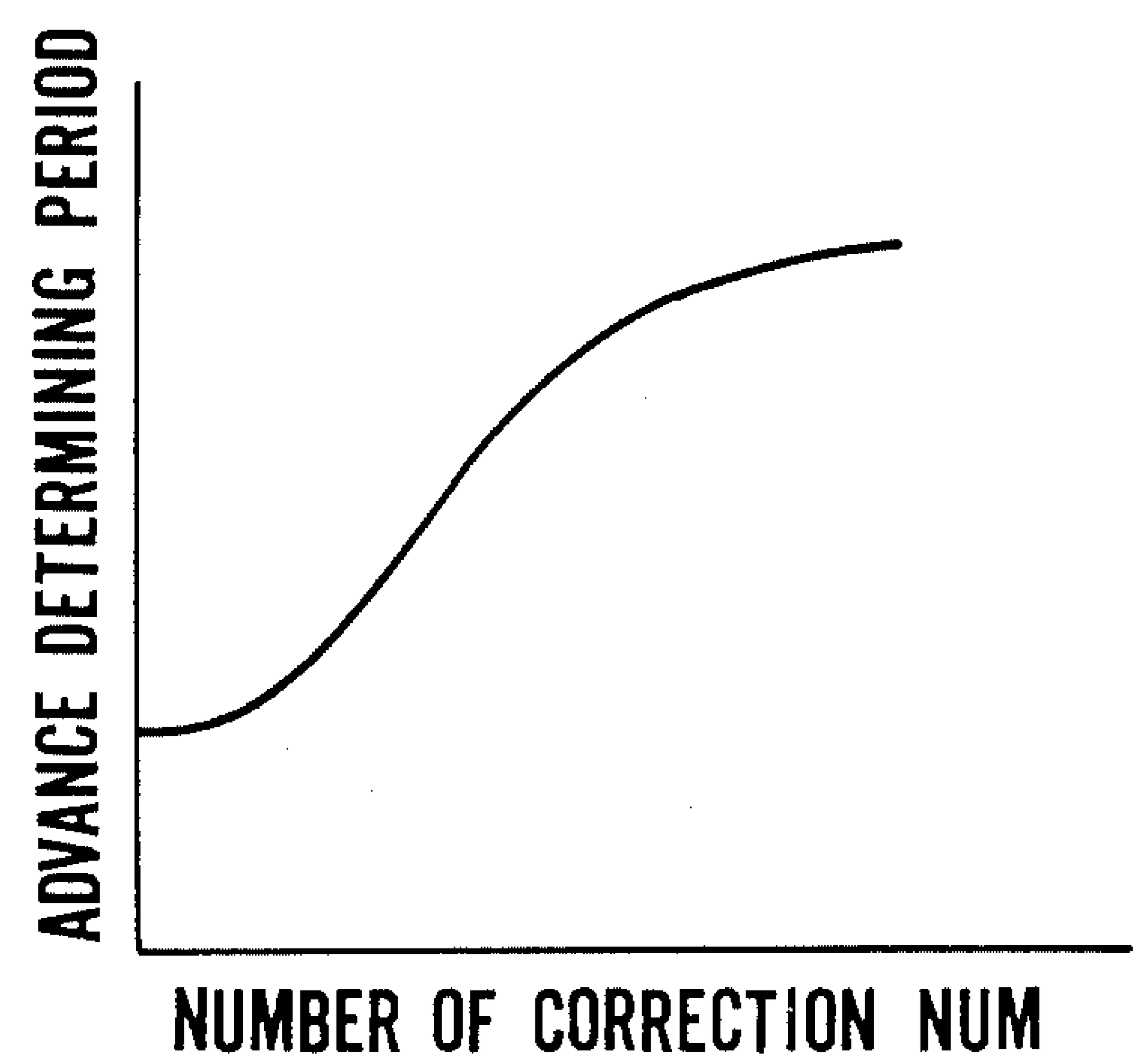


FIG. 10b

SYSTEM AND METHOD FOR CONTROLLING THE IGNITION TIMING OF AN INTERNAL COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

The present invention relates to a system and method for controlling the ignition timing of an internal combustion engine such as an automotive engine.

A learning control system for correcting the ignition timing has been proposed. The control system is adapted to advance the ignition timing so as to produce a maximum torque as long as the level of engine knocking does not exceed a tolerable level. The ignition timing stored in a RAM is corrected by a small correcting quantity (quantity of correction) and converged to a desired value little by little. The correcting quantity for the ignition timing at every updating operation is gradually reduced as the number of the learning increases, that is as the ignition timing approaches the desired value.

On the other hand, when the engine is accelerated, the ignition timing is reduced in order to increase the power of the engine. In a conventional ignition timing learning control system, a single program is provided for correcting the ignition timing including the ignition timing for the acceleration. Since the program is provided for correcting the timing at steady state of engine operation, the program comprises a plurality of steps in order to finely correct the timing. Accordingly, it takes a long time to advance the timing at the acceleration. As a result, the ignition can not be sufficiently advanced to meet the requirement of the acceleration.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a system and method which may quickly correct the ignition timing at acceleration of an engine.

Another object of the present invention is to provide a system and method which may correct the ignition timing to a maximum advance value within an allowable range so as to produce the largest torque.

To this end, in the system and method of the present invention, the corrections of the timing at the acceleration and at the steady state are independently performed, respectively.

According to the present invention, there is provided a system and method for controlling the ignition timing of an internal combustion engine having a microprocessor and an ignition timing control device comprising, first sensing means for sensing operating conditions of the engine at steady state and for producing an engine operating condition signal, second sensing means for sensing the acceleration of the engine and for producing an acceleration signal, and a knock sensor for sensing engine knock and for producing a knock signal.

The system further comprises first means responsive to the engine operating condition signal and knock signal for producing a first ignition timing correcting signal representing an ignition timing correcting quantity at a time for deciding the ignition timing and for producing a basic ignition timing based on the first ignition timing correcting signal, second means responsive to the acceleration signal and the knock signal for obtaining from a table a second ignition timing correcting signal representing an ignition timing correcting quantity for correcting the basic ignition timing decided by the first ignition timing correcting signal.

The other objects and features of this invention will become apparently understood from the following description with reference to the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a block diagram showing a control system according to the present invention;

FIG. **2** is a block diagram showing a main part of the control system;

FIGS. **3a** and **3b** show tables storing a plurality of ignition timings;

FIG. **4** shows a range of a coefficient K;

FIGS. **5a** to **5c** are tables for an acceleration subroutine;

FIGS. **6**, **7**, **8**, **9a** and **9b** are flow charts showing the operation of the system; and

FIGS. **10a** and **10b** show a retard coefficient table and an advance determining period table, respectively.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **1**, an intake air pressure (or quantity) sensor **1**, engine speed sensor **4** such as a crankangle sensor, and knock sensor **7** are provided to detect engine operating conditions. The output of the sensor **1** is applied to an A/D converter **3** through a buffer **2**, and the output of the sensor **4** is applied to an interrupt processing circuit **6** through a buffer **5**. The output of the knock sensor **7** is applied to a comparator **12** through a filter **8** and an amplifier **9**, and, on the other hand, to the comparator **12** through a rectifier **10** and amplifier **11**. The comparator **12** compares both inputs and produces an output signal when an engine knock having a higher level than a predetermined value is generated. The outputs of the A/D converter **3**, circuit **6** and comparator **12** are applied to a microprocessor **18** through an input port **13**.

The microprocessor **18** comprises a CPU **15**, RAM **16**, ROM **17** and output port **14**. The output of the microprocessor **18** is applied to an ignition timing control device **21** through a driver **19** so as to control the ignition timing in accordance with the engine operating conditions sensed by the sensors **1**, **4** and **7**.

FIG. **6** shows summarizes the operation of the control system. When the program starts, engine speed and intake air pressure are calculated at a step **61**, and the difference between the pressures at the program and at the last program is calculated. Further, an acceleration determining value at the engine speed is read from an acceleration determining value table **33** of FIG. **5a** at a step **62**. Thereafter, it is determined, at a step **63**, whether the engine is accelerated by comparing the pressure difference with an acceleration determining value read out at the step **62**. If the difference is larger than the value, it is determined that the engine is accelerated. When the engine is accelerated, the program proceeds to a correction subroutine **64** for acceleration ignition timing. In the subroutine, a correcting quantity (quantity of correction) for the acceleration is obtained and stored in the RAM **16**.

If the engine is not accelerated, the program proceeds to a step **65**, where it is decided whether a rough correction has been executed (if a rough correction completion flag RCMP is set). In accordance with the decision, a rough correction or a fine correction is executed in a rough correction subroutine **66** or a fine correction subroutine **67**. In the subroutine **66**, a basic ignition timing is obtained and the timing is corrected at a step **68** by a correcting quantity obtained in the subroutine **64** or **67**, as described hereinafter. If the basic ignition timing obtained in the rough correction subroutine largely deviates from a new desired value by a large disturbance during the fine correcting operation in the subroutine **67**, the correcting quantity in the subroutine **67** becomes very large. In such a case, it takes a long time to correct the deviation. Accordingly, if the correcting quantity exceeds a predetermined value at at step **69**, the rough correction completion flag RCMP is reset at a step **70**, whereby the deviation is quickly corrected in the rough correction subroutine **66**.

The rough correction is an operation for obtaining a basic ignition timing SPK_{bs} which is calculated in a basic ignition timing setting circuit **40** shown in FIG. **2**. FIG. **8** shows the operation of the rough correction. At a step **91**, the engine speed and intake air pressure are calculated based on the outputs signals of the sensors **1** and **4**. Thereafter, at a step **92**, a first maximum ignition timing MAPSTD and a second maximum ignition timing MBT are read from tables **92a** and **92b** (FIGS. **3a**, **3b**) in the ROM **17**, in accordance with the engine speed and intake air pressure. The first maximum ignition timing is maximum timing for producing maximum torque with low-octane gasoline without occurrence the knocking and the second maximum ignition timing is maximum timing for producing maximum torque with high-octane gasoline without knock occurring.

In the system, a coefficient K for correcting the ignition timing is provided. The value of the coefficient K is preliminarily set to a value between zero and 1 as shown in FIG. **4**.

The coefficient K is stored in the RAM **16** and updated in accordance with engine operating conditions so as to roughly converge the ignition timing to a desired ignition timing. The updating is performed under a predetermined condition and the condition is determined at a step **93**. When the difference between the first and second maximum ignition timings read from the tables **92a** and **92b** (FIG. **3a** and **3b**) is larger than a predetermined degree, for example 5°, the updating is performed. Namely, the program proceeds to a step **94**, where it is determined whether a knock has occurred during the program. When the occurrence of knock is determined, the program proceeds to a step **95**, and if not, proceeds to a step **96**. At step **95**, the coefficient K is decremented by a correcting quantity $\Delta K(\Delta K = K/2)$, and the remainder $K-\Delta K$ is stored in the RAM **16** as a new coefficient for the next updating. Accordingly, the correcting quantity ΔK at the next updating is $(K-\Delta K)/2$. Namely, the correcting quantity is one-half of the coefficient K at updating. More particularly, if the initial coefficient is $\frac{1}{2}$, the correcting quantity is $\frac{1}{4}$, and if it is 0 or 1, the correcting quantity is $\frac{1}{2}$ as seen from FIG. **4**.

At the step **96**, it is determined whether the engine has operated without knock occurring for a predetermined period. When knocking does not occur for the period, the coefficient K is incremented by the correcting quantity ΔK at a step **97**.

After the updating of the coefficient K at step **95** or **97**, it is determined whether the rough correction is completed at a step **98**. As will be understood from the above description, the correcting quantity ΔK decreases as the number of the correction increases. In the system, when the correcting quantity reaches a predetermined small value, the rough correction is completed. Accordingly, if the quantity ΔK reaches the predetermined value, a rough correction completion flag RCMP is set at a step **99**, or if not, the flag is reset at a step **100**. On the other hand, the total correcting quantity SPK_{prt} and the number of correction NUM of the ignition timing is stored in an ignition timing correcting quantity table **42** and a table **43** (FIG. **2**) for the number of the correction. At a step **100a**, a basic ignition timing SPK_{bs} is calculated by the following formula

$$SPK_{bs} = MAPSTD + K \times \Delta MAPMBT \quad (1)$$

where $\Delta MAPMBT = MBT - MAPSTD$

The basic ignition timing is applied to an engine **41** (FIG. **2**) to operate the engine at the ignition timing. The coefficient K is stored in the RAM **16**. If the rough correction is not completed, the coefficient K is updated at the next program so as to roughly converge the ignition timing to a desired ignition timing as described above. It will be understood that if the initial coefficient K is 0, the basic ignition timing SPK_{bs} calculated by the formula (1) is the maximum ignition timing MAPSTD at the first program. The basic ignition timing SPK_{bs} obtained by the rough correction is further corrected by the fine correcting operation as described hereinafter.

Referring to FIGS. **9a** and **9b**, at a step **102**, it is decided whether the engine operation is in a range which is proper to correct the basic ignition timing SPK_{bs}. If it is in the range, the correcting quantity SPK_{prt} and the number of correction NUM are read from tables **42** and **43** at a step **103**. Then, at a step **104**, a retard coefficient LN for retarding quantity RET is looked up from a retard coefficient table **44** (FIG. **2**) of FIG. **10a** in accordance with the number of correction NUM, and an advance determining period ADJ is looked up from an advance determining period table **45** (FIG. **2**) of FIG. **10b** in accordance with the number of correction NUM. Thereafter, the program proceeds to a step **105**, where it is decided whether a knock has occurred during the program. When the occurrence of knocking is determined, the program proceeds to a step **106**, and if not, it proceeds to a step **109**. At step **106**, the intensity of the knocking and the interval of the knocks are calculated at a calculating circuit **47** (FIG. **2**), and then, the retarding quantity KNK is looked up from a retarding quantity table **48** in accordance with the intensity and the interval of the knocking. At a step **107**, a real retarding quantity RET_{real} is calculated by multiplying the retarding quantity KNK and retard coefficient LN together ($RET_{real} = KNK \times LN$). Thereafter, the program proceeds to a step **108**, where the correcting quantity SPK_{prt} stored in the table **42** is subtracted with the real retarding quantity RET_{real} to obtain a new correcting quantity SPK_{prta} which is stored in the table **42**.

On the other hand, at the step **109**, it is decided whether a knock occurred in the advance determining period ADJ, which is performed at a comparator **49** in FIG. **2**. When knocking does not occur in the period, the program proceeds to a step **110**, where an advancing quantity ADV of a constant small value is added to the correcting quantity SPK_{prt} to obtain a new correcting quantity SPK_{prta} which is performed in an advancing quantity setting circuit **50** in FIG. **2** and stored in the table **42**. Thereafter, at a step **111**, it is determined whether the new correcting quantity SPK_{prta} is larger than a limit value which is obtained by subtracting the basic ignition timing SPK_{bs} from the maximum ignition timing MBT ($MBT-SPK_{bs}$). When the new correcting quantity SPK_{prta} is smaller than the limit value, the new correcting quantity is stored in the table **42** at a step **113**. If it is larger than the limit value, the value of $MBT-SPK_{bs}$ is used as a new correcting quantity (at step **113**) and stored in the table **42**. The stored value SPK_{prta} is added to the basic ignition timing SPK_{bs} at step **68** (FIG. **6**).

Explaining the operation in the subroutine **64** for acceleration with reference to FIG. **7**, the occurrence of engine a knock is decided at a step **81**. When knock occurs, the intensity of the knock is calculated at a step **82**. In accordance with the intensity, retarding degree RET_{acc} of ignition timing is looked up from a table of FIG. **5c** at a step **83**. On the other hand, correcting degree SPK_{acc} is looked up from a table **34** of FIG. **5b** in accordance with the engine speed, and the retarding degree RET_{acc} and the correcting degree SPK_{acc} are added to produce a correcting quantity SPK_{acr}. The correcting quantity SPK_{acc} is stored in the RAM **16** at a step **89** for correcting the basic ignition timing obtained in the subroutine **66**.

If knock does not occur, it is determined whether knock does not occur during a predetermined period at a step **85**. It is does not occur, the program proceeds to a step **86** where a predetermined advancing degree ADV_{acc} is subtracted from the correcting degree SPK_{acc} ($SRK_{acc}-ADV_{acc}$) to obtain a correcting quantity SPK_{aca}. Thereafter, the program proceeds to a step **87**, where it is determined whether the correcting quantity SPK_{acc} is negative. If the SPK_{aca} is negative, the value of SPK_{aca} is set to zero at a step **88**. The value is stored in the RAM **16** at the step **89**. The stored value SPK_{acr} or SPK_{aca} is added to the basic ignition timing SPK_{bs} at step **68** (FIG. **6**) to obtain a real ignition timing SPK. The data stored in the table **34** (FIG. **5b**) is rewritten with the value SPK_{aca} or SPK_{acr} for the next correction.

In accordance with the invention, since the correction of the ignition timing at acceleration is independent from the correction at steady state, it is possible to quickly correct the timing by adding a large correcting quantity.

While the presently preferred embodiment of the present invention has been shown and described, it is to be understood that this disclosure is for the purpose of illustration and that various changes and modifications may be made without departing from the scope of the invention as set forth in the appended claims.

What is claimed is:

1. A system for controlling the ignition timing of an internal combustion engine having a microprocessor and an ignition timing control device comprising:

first sensing means for sensing operating conditions of the engine at steady state and for producing an engine operating condition signal;

second sensing means for sensing the acceleration of the engine and for producing an acceleration signal;

a knock sensor for sensing engine knock and for producing a knock signal;

first means responsive to the engine operating condition signal and knock signal for producing a first ignition timing correcting signal representing an ignition timing correcting quantity at a time for deciding the ignition timing and for producing a basic ignition timing based on the first ignition timing correcting signal;

second means responsive to the acceleration signal and the knock signal for obtaining from a table a second ignition timing correcting signal representing an ignition timing correcting quantity for correcting the basic ignition timing decided by the first ignition timing correcting signal.

2. A method for controlling the ignition timing of an internal combustion engine having a microprocessor and an ignition timing control device comprising the steps of:

sensing operating condition of the engine at steady state and producing an engine operating condition signal;

sensing the acceleration of the engine and producing an acceleration signal;

sensing engine knock and producing a knock signal;

producing a first ignition timing correcting signal representing an ignition timing correcting quantity at a time for deciding the ignition timing in response to the engine operating condition signal and knock signal and producing a basic ignition timing based on the first ignition timing correcting signal; and

obtaining from a table a second ignition timing correcting signal representing an ignition timing correcting quantity in response to the acceleration signal and the knock signal and correcting the basic ignition timing decided by the first ignition timing correcting.

* * * * *